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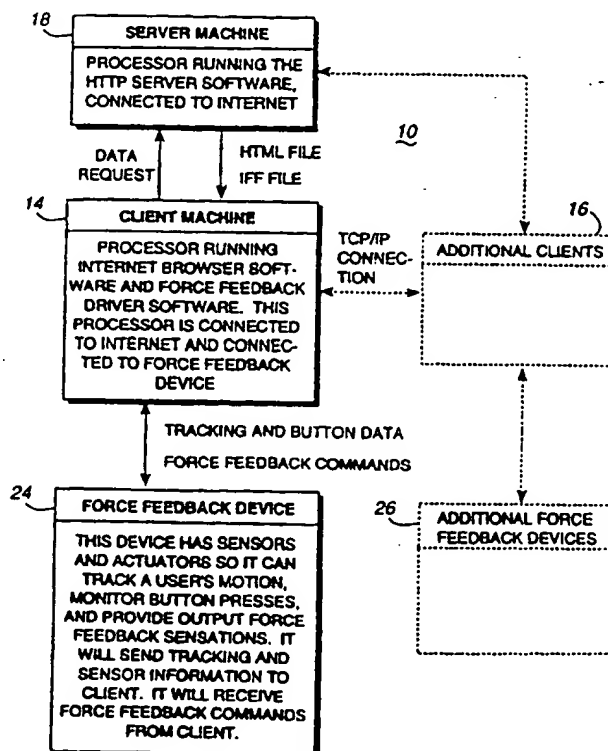
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(54) Title: METHOD AND APPARATUS FOR PROVIDING FORCE FEEDBACK OVER A COMPUTER NETWORK

(57) Abstract

An internet network force feedback system (10) which includes a server machine (18), a client machine (14) provided with the force feedback device (24), and one or more additional client machines (16) each of which may be provided with additional force feedback devices (26). The server machine is a computer or processor running TCP/IP server software and is connected to the Internet. The client machine (14) runs internet browser software. The force feedback device (24) has sensors and actuators to monitor the input of the user and transmit the input to the client and receive response from the client and provide the force feedback sensations to the user.



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Method and Apparatus for Providing Force Feedback Over a Computer Network

Background of the Invention

This invention relates generally to human/computer interfaces, and more particularly to human/computer interfaces with force feedback that can operate over a network.

10 The Internet has, of late, become extremely popular. The origins of the Internet date back several decades to a U.S. government sponsored military/research/business wide area network (WAN) that was designed to remain operational even in the event of the catastrophe, e.g. a major earthquake or a nuclear war. To accomplish this goal, robust protocols and systems were developed which allowed a geographically distributed collection of computer systems to be  
15 connected as a WAN such that the loss of a particular computer, or group of computers, would not preclude the continued communication among the remaining computers.

While the use of the Internet has been prevalent for many years now, its use has been limited by the arcane and difficult commands required to access the various computers on the network. To address this problem, a protocol known as the "World Wide Web" or "WWW" was  
20 developed to provide an easier and more user-friendly interface for the Internet. With the World Wide Web, an entity having a domain name creates a "web page" or "page" which can provide information and, to a limited degree, some interactivity.

A computer user can "browse", i.e. navigate around, the WWW by utilizing a suitable web browser and a network gateway (e.g., an Internet Service Provider (ISP)). For example,  
25 UUNET, America Online, and Global Village all provide Internet access. Currently, the most popular web browser, known as the Netscape® Navigator®, is made by Netscape Corporation of Mountain View, California. The web browser allows a user to specify or search for a web page on the WWW, and then retrieves and displays web pages on the user's computer screen.

The Internet is based upon a transmission protocol known as "Transmission Control  
30 Protocol/Internet Protocol" (or "TCP/IP" for short), which sends "packets" of data between a host machine, e.g. a server computer on the Internet, and a client machine, e.g. a user's personal computer connected to the Internet. The WWW is an Internet interface protocol which is supported by the same TCP/IP transmission protocol. Intranets are private networks based upon Internet standards, and have become quite common for managing information and  
35 communications within an organization. Intranets, since they adhere to Internet standards, can often use the same web browser software and web server software as are used on the Internet.

A web page typically includes static images and text. The images and text are specified in a "HyperText Mark-up Language" ("HTML") file that is sent from the web server to the client machine. This HTML file is parsed by the web browser in order to display the text and images  
40 on the display of the client machine. Other standardized languages or protocols are also being

5 developed for use with the Internet and the World Wide Web. For example, the Virtual Reality Modeling Language (VRML) is used to provide visual virtual 3-D environments and allow one or many users to navigate through and interact as "avatars" in such an environment, using a client computer system.

10 The Internet and the WWW also permit sound data to be transmitted over the Internet. For example, references to sound files can be embedded in HTML pages and can be played by the web browser. Data "packets" coded in TCP/IP format can also be sent from one client machine to another over the Internet to transmit sound data. This last-mentioned technique forms the basis for Internet telephony.

15 While the transmission of visual images (both static and dynamic, *i.e.* video), text, and sound over the Internet is well-known, the transmission of other types of sensory data has not been well explored. In particular, the transmission of data over the Internet pertaining to the sense of touch and/or force has not been established. "Force feedback" allows a user to experience or "feel" tactile sensations as provided through computational information. Using computer-controlled actuators and sensors on a force feedback device, a variety of realistic  
20 sensations can be modeled and experienced by the user. This useful and highly immersive sensory modality for interacting with the Internet has hereto been unavailable.

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Summary of the Invention

The present invention is related to the transmission of information pertaining to a subset of the sense of touch, *i.e.* the transmission of forces to a user over a computer network system. The "force feedback" provided by the methods and apparatus of the present invention enhance the sensory experience of the user to provide a richer, more interesting, and more enjoyable experience.

In a preferred method of the present invention for providing force feedback over a network, a connection is first established between a server machine and a client machine. The client machine (typically a personal computer), has a visual display (*e.g.*, a computer video monitor) and a force feedback human/computer interface device. Examples of force feedback human/computer interfaces (hereafter "force feedback devices") include force feedback joysticks, mice, trackballs, steering wheels, and yokes. In some embodiments of the present invention, the force feedback device preferably constrains movement to two degrees of freedom to match a two-dimensional configuration of the visual display. Three or more degrees of freedom of movement can be provided in other embodiments. Next, the client machine receives from the server machine both screen display information and force feedback information that is related to the screen display information. Preferably, the screen display information and force feedback information are encoded in an HTML web page file. Files and data in other protocols or languages can also be used, such as VRML. Next, the client machine displays on the monitor an image generated from the screen display information. The force feedback device provides a pointer event and/or a button event to the client with respect to the screen image, and a force feedback signal is computed based upon the detected events and the force feedback information stored on the client machine. Finally, a force feedback is provided to a user by the force feedback device based upon the force feedback signal.

Preferably, the force feedback device is provided with a local microprocessor which communicates with the client machine. The force feedback device further includes sensors and actuators coupled to the local microprocessor such that the force feedback signal can take the form of a relatively high-level force feedback command. The local microprocessor parses the force feedback command to control the actuators of the human/computer interface in a control loop with the sensors.

Another preferred method of the present invention for providing force feedback over a network establishes a connection between a first computer and a second computer over a network. The first computer includes a computer input device which develops a first computer input, and a second computer includes a visual display and a force feedback device for providing a second computer input. The computer input device of the first computer may or may not also be a force feedback device. A screen image is displayed on the monitor of the second computer that is associated with stored force feedback information. A computer input is received from the first

5 computer over the network, and a force feedback signal, based on the stored force feedback information and upon at least one of the first computer input and the second computer input, is determined. Finally, a force feedback is provided with the force feedback device in response to the force feedback signal such that it is correlated with the screen image on the second computer.

10 A preferred method of the present invention for providing force feedback over a network supporting TCP/IP protocols includes: (a) sending a connection request from a client computer over a network supporting TCP/IP protocols to a web server connected to the network that is hosting a desired URL; (b) receiving, parsing, and interpreting (*i.e.* "processing") an HTML file at the client computer that was sent from the web server in response to the connection request, wherein the processing includes parsing an embedded force object reference having associated parameters and  
15 building a force object that is specified by the force object reference and the parameters; (c) developing a force feedback signal from the force object; and (d) providing force feedback to a user of the force feedback device coupled to the client computer in response to the force feedback signal. Preferably, the HTML file is a web page of the web server and the parsing is provided by an enhanced web browser. Even more preferably, the web browser is provided with a software "plug-  
20 in" to aid in the processing of the embedded force object reference, the building of the force object, and the development of the force feedback signal.

A network force feedback system in accordance with the present invention includes a network, a first computer coupled to the network, and a second computer coupled to the network, where the second computer includes a visual display and a force feedback device capable of  
25 providing a second computer input to the second computer, and further being capable of providing force feedback to a user in response to a force feedback signal provided by the second computer. Preferably, the force feedback device includes a local microprocessor that communicates with the second computer such that the force feedback signal can take the form of a relatively high-level force command. The second computer develops an image on the visual display that is correlated to stored  
30 feedback information, such that the second computer produces the force feedback signal in response to at least one of information provided from the first computer and of the second computer input. The first computer can either be a server computer or, like the second computer, another client computer coupled to the network. The present invention therefore permits a computer user to experience force feedback over the network.

35 In the network force feedback system, information pertaining to force feedback can be downloaded from a server computer to the second or "client" machine. Alternatively, force feedback signals can be sent over the network between a first "client" machine and a second "client" machine on a peer-to-peer basis, or from a server to one or more peers in a server-to-peer basis.

The present invention adds a new sensory modality when interacting with a networked  
40 computer system. More particularly, force information can be either downloaded to a client machine from a server machine connected to the network, or force information can be passed between two or

- 5 more client machines on the network. When force information is downloaded from a server, the client machine parses and interprets the force information and directly controls its interaction with the force feedback device on an essentially real-time basis. In contrast, peer-to-peer or server-to-peer direct interaction over the network may be subject to some transmission ("latency") delays, but permits remote interactivity with a client's force feedback device.
- 10 These and other advantages of the present invention will become apparent upon reading the following detailed descriptions and studying the various figures of the drawings.

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Brief Description of the Drawings

Fig. 1 is a pictorial representation of the Internet, a web server machine, and two client machines;

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Fig. 2 is a block-diagram of a client machine used in the present invention;

Fig. 3 is a block-diagram of a force feedback system in accordance with the present invention;

Fig. 4a is a perspective view of a preferred human/computer interface ("force feedback device") of the present invention;

15

Fig. 4b is a cross-sectional view taken along line 4b-4b of Fig. 4a;

Fig. 5a is a perspective view of another preferred embodiment for a force feedback device in accordance with the present invention;

Fig. 5b is a perspective view of a first alternate embodiment for the force feedback device of Fig. 5a;

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Fig. 5c is a perspective view of a second alternate embodiment of the force feedback device of Fig. 5a;

Fig. 6 is a block diagram of a wide area network (WAN) based upon Internet TCP/IP protocol and supporting World Wide Web (WWW) HTML protocols in accordance with the present invention;

25

Fig. 7a is flow-diagram of a "Acquire URL" process in accordance with the present invention;

Fig. 7b is an example of an HTML file of the present invention sent from a web server machine to a client machine;

Fig. 8 is a flow-diagram of the "Parse and Interpret HTML Component" step of Fig. 7a;

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Fig. 9 is a flow-diagram of the "Plug-in Interpret .IFF File" step of Fig. 8;

Fig. 9a is an illustration of an image displayed on a visual display of a client computer as generated from a downloaded HTML web page file; and



- 5        Fig. 10 is a flow-diagram of a process for monitoring the "pointer state" of the force feedback device of the present invention.

5

Detailed Description of the Preferred Embodiments

In Fig. 1, a network system 10 includes a wide area network (WAN) such as the Internet 12, and a number of computers or "machines" coupled to the Internet 12. For example, a first client machine 14, a second client machine 16, and a web server machine 18, are coupled to the Internet 12.

As noted previously, both the Internet 12 and Intranets operate using the same TCP/IP protocols. This allows Intranets to use similar or the same server machine software and client machine software as are used in Internet 12 applications. Therefore, it will be apparent to those skilled in the art that the following descriptions apply equally well to Internet, Intranet, and other forms of network systems that are compatible with the processes and apparatus disclosed herein.

The Internet 12 includes a number of nodes 20 that are interconnected by data transmission media 22. These nodes are typically routers, switches, and other intelligent data transmission apparatus which route "packets" of TCP/IP information to the desired destination. In some instances, the nodes 20 comprise an Internet service provider (ISP) 20a which allows a client machine to access the "backbone" of the Internet. Alternatively, client machines and web servers can be coupled directly into the backbone of the Internet.

As noted previously, the present invention is directed to the implementation of force feedback over a network, such as the Internet 12. To provide a user of a client machine with the experience of force feedback, force feedback human/computer interfaces (hereafter "force feedback devices") 24 and 26 can be provided as part of the client machines 14 and 16, respectively. The client machines 14 and 16 are typically provided with computer video monitors 28 and 30 (which is one example of a "visual display"), respectively, which can display images I1 and I2, respectively. Preferably, forces developed by force feedback devices 24 and 26 are correlated with the images I1 and I2 of the client machines 14 and 16, respectively.

The machines 14-18 are considered, in the language of the Internet, to be "resources," and each has its own unique Uniform Resource Locator or "URL." In one embodiment of the present invention, a client machine, such as client machine 14 or 16, sends a request for a "web page" residing on, for example, web server machine 18. This is accomplished by the client machine sending a connection request and a URL which specifies the address of the web page to the web server machine 18. The web server machine 18 then sends a web page 32 written in HTML format back to the requesting client machine where it is "cached" in the memory (typically the RAM, hard disk, or a combination of the two) of the client machine. In this embodiment of the invention, the image on the video display of the client machine is generated from the HTML web page file cached

5 on the client machine, and force feedback is provided to a user through the force feedback device as he manipulates a user manipulable object of the force feedback device.

In another aspect of the present invention, a first client machine, such as client machine 14, and a second client machine, such as client machine 16, directly communicate force feedback commands to each other in standard TCP/IP protocol over the Internet 12. More particularly, client machine 14 can send force feedback and other information to the URL of the client machine 16, and the client machine 16 can send force feedback and other information in standard TCP/IP packets to the URL of the client machine 14. In this way, users of client machine 14 and client machine 16 can interact physically over the Internet 12. Of course, a server machine 18 can likewise directly communicate force feedback commands to a client machine 12 or 14, or all three machines can interact.

In Fig. 2, a "personal" computer 34 architecture that can be used for client machine 14 or client machine 16 is shown in block diagram form. It should be noted that a variety of machine architectures can be used to access the Internet 12, i.e. can be used as "network access computers." The particular architecture shown for the computer 34 is a typical personal or "PC" computer architecture, such as that used with IBM compatible personal computers. Web server machines can also have similar architectures, but are often more powerful computers known as "workstations" that operate under some variant of the UNIX<sup>®</sup> operating system. The Internet service providers 20a are likewise often UNIX-based computers or powerful personal computers running Windows NT<sup>®</sup>. The nodes 20 are most commonly routers built by Cisco Systems of San Jose, California. Client machine 14 or 16 can also take other forms, such as a television including or connected to a microprocessor for Internet access. Force feedback devices used with such client machines can be appropriate for the particular embodiment, e.g., a TVremote control used for internet browsing on the abovementioned television can include force feedback functionality.

The personal computer system 34 includes a microprocessor 36 clocked by a system clock CLK and which is coupled to a high speed or memory bus 38 and to a lower speed or I/O bus 40. The system RAM 42 and ROM 44 are typically coupled to the high speed memory bus, while various peripherals, such as the video display, hard disk drive, Internet interface (often either a modem or an Ethernet connection), and force feedback device, are typically coupled to the slower I/O bus. The microprocessor executes programs stored in the various memories (RAM, ROM, hard disk, etc.) of the personal computer 34 to control, for example, the image display on the video display and the forces provided by the force feedback device. The manufacture and use of personal computers, such as personal computer 34, are well-known to those skilled in the art.

In Fig. 3, a client machine 46 in accordance with the present invention includes a personal computer system 48 and a force feedback human/computer interface or "force feedback device" 50. A user 52 can receive visual information 54 and auditory information 56 from the personal computer 48 and can manipulate the force feedback device 50 as indicated at 58a and 58b to provide input.

5 e.g., to command a cursor location on a visual display or other provide other control information. In addition, the user 52 can receive force feedback 60 from the force feedback device 50 to represent physical "feel" sensations.

The personal computer system 48 includes the microprocessor 36, the system clock 62, a video monitor 64 (which is one type of "visual display"), and an audio device 66. The system clock  
10 62, as explained previously, provides a system clock signal CLK to the microprocessor 36 and to other components of the personal computer system 48. The display device 64 and the audio output device 66 are typically coupled to the I/O bus 40 (not shown in this figure).

In this preferred embodiment, the force feedback device 50 preferably includes a local microprocessor 68, a local clock 70, optional local memory 71 for the local microprocessor 68, a  
15 sensor interface 72, sensors 74, a user manipulatable object 76, "other" input interface 78, an actuator interface 80, a safety switch 82, and actuators 84 which provide a force  $F$  to the object 76, and an optional power supply 86 to provide power for the actuator interface 80 and actuator 84.

The microprocessor 36 of the personal computer system 48 is coupled for communication with the local microprocessor 68 of the force feedback device 50. This communication coupling can  
20 be through a serial port coupling 88 to the personal computer system, or through a game port coupling 90 to the personal computer system. Virtually all personal computer systems built to the IBM PC/AT standards will include a serial port and a game port. As noted, the serial port will permit two-way communication between microprocessor 36 and microprocessor 68, and thus is preferable over the game port coupling which only permits one-way communication from the local processor 68  
25 to the microprocessor 36. In consequence, a serial port connection between the personal computer system 48 and the force feedback device 50 will permit force feedback commands to be sent from the microprocessor 36 to the local microprocessor 68, while a game port connection alone will not be able to provide this function. However, some simpler forms of "reflex" type force feedback can still be provided by the force feedback device 50 under the control of the local microprocessor 68 even if  
30 only a game port interface is used. It should also be noted that the microprocessor 36 and a local microprocessor 68 can communicate over both the serial port connection and the game port connection to provide a greater communication bandwidth. A preferred serial port is the Universal Serial Bus (USB) of a personal computer, although an RS-232 serial bus, or other serial busses, a parallel bus, an ethernet bus, or other types of interfaces or communication links can also be used.

35 In use, the user 52 of the client machine 46 grasps the object 76 of the force feedback device 50 and manipulates (*i.e.* exerts a force to move or attempt to move) the object to cause a "pointer" icon to move in the image displayed by the display device 64. This pointer icon typically takes the form of a small arrow, a pointing hand, or the like. The sensor 75 senses the movement of the object 76 and communicates the movement to the local microprocessor 68 through the sensor interface 72.  
40 The local microprocessor 68 then communicates through serial port 88, game port 90, or both to the microprocessor 36 to cause the microprocessor 36 to create a corresponding movement of the pointer

5 icon on the image displayed upon the visual display 64. In some embodiments, the sensors 74 can communicate directly to microprocessor 36 without the use of local microprocessor 68. The user can also create other input, such as a "button click," through the other input 78 which are communicated to the microprocessor 36 by the local microprocessor 68 or directly, e.g., using a game port.

10 If the pointer icon on the display device 64 is at a position (or time) that correlates to a desired force feedback to the user 52, the microprocessor 36 sends a force feedback command to the local microprocessor 68 over the serial port connection 88. The local microprocessor 68 parses this force feedback command and sends signals to the actuator interface 80 which causes the actuator 84 to create forces  $F$  on object 76, which are experienced by the user 52 as indicated at 60. The safety switch 82, sometimes referred to as a "deadman switch", blocks the signal from the actuator interface 15 80 if, for example, the user 52 is no longer grasping the object 76. In this way, the user 52 can interact with the client machine 46 in a visual, auditory, and tactile fashion.

In Fig. 4a, a force feedback device 50a is provided with a user manipulatable object 76a which, in this instance, includes a shaft 90 and a ball-grip (or joystick) 92. The force feedback device 50a also includes a pair of linear voice coil actuators ("voice coils") 94 and 96 that can serve 20 both as sensors and actuators. Alternatively, the voice coils can be used only as actuators, and separate sensors (not shown) can be used. The voice coil 94 is coupled to the shaft 90 of object 76a by a first link 98 and a second link 100. Link 98 is coupled to link 100 with a pivot 102, and a link 100 is coupled to the shaft 90 by a pivot 104. Similarly, voice coil 96 is coupled to the shaft 90 of the object 76a by a first link 106 and a second link 108. The first link 106 is coupled to second link 25 108 by a pivot 110, and the link 108 is coupled to the shaft 90 of the object 76a by the pivot 104.

The link 98 can move in and out of a housing 112 as indicated by arrow 114, and link 106 can move in and out of a housing 116 of voice coil 96 as indicated by the arrow 118. The pivots 102, 104, and 110 allow the object 76a to move within the constraints of an x-y plane, but does not permit movement in a z direction orthogonal to the x-y plane. Therefore, the force feedback device is 30 a two degree (2D) of freedom device. That is, the user manipulatable object 76a can move with a first degree of freedom in a x direction, and in a second degree of freedom in the y direction. A 2D force feedback device 50a is considered preferable in the present invention since it correlates well to the two-dimensional screen of a monitor of a client machine.

In Fig. 4b, a voice coil 94 is shown in a cross sectional view taken along line 4b-4b of Fig. 35 4a. The housing 112 includes a central core 120 and a number of elongated magnets 122. An armature 124 includes a hollow, cylindrical member having inner surface 126 which slidably engages the core 120. Wrapped around the armature 124 are coils 128. The coils are electrically coupled to actuator and/or sensor interfaces. A plate 130 is attached to the end of the armature 124 and is coupled to the link 98. The armature 124 and link 98 can move in a linear fashion as indicated 40 at 114. Other voice coil configurations can also be used, such as differently shaped cores, different

5 coil layouts, etc. In addition, other types of actuators can be used instead of or in addition to voice coils in force feedback device 50, such as DC motors, brakes, pneumatic actuators, etc.

In Fig. 5a, an alternative embodiment of a force feedback device 50b is illustrated. The force feedback device 50b has many points of similarity with the force feedback device 50a, with like reference numerals referring to like elements. The force feedback device 50b includes the user  
10 manipulatable object 76a, the shaft 90, the ball knob 92, and the voice coils 94 and 96. However, the links of the force feedback device 50a have been replaced by flexure members. More particularly, the links 98 and 100 of force feedback device 50a have been replaced by a rigid connector 132 and a flexible member 134 (collectively comprising a "flexure member"), and the links 106 and 108 of the force feedback device 50a have been replaced by a connector member 136 and a  
15 flexible member 138 (also collectively comprising a flexure member). The connector 132 is rigidly is attached to the plate 130 at the end of the armature of the voice coil 94 and is rigidly attached to an end of the flexible member 134. The other end of the flexible member 134 is attached to a base 140 which, in turn, is rigidly attached to the shaft 90 of the object 76a. Similarly, the connector 136 is attached to a plate of an armature of voice coil 96 at one of its ends, and is attached to the flexible  
20 member 138 at the other of its ends. The remaining end of flexible member 138 is rigidly attached to the base 140.

The flexible members 134 and 138 serve the same functions as the links of the force feedback device 50a described previously. As the object 76a is moved back and forth along an x-y plane, the flexible member 134 can move in and out of the voice coil housings 94 and 96, respectively, and can  
25 bend to accommodate angular movement with respect to the x and y axis. This permits the connectors 132 and 136 to move back and forth within the voice coils 94 and 96, respectively

In Fig. 5b, an alternative user manipulatable object 76a takes the form of a stylus 142 which can engage an aperture 144 in an alternative base 140'. The alternative base 140' can be coupled to the flexible members 134 and 138 of the embodiment of Fig. 5a. Alternatively, the tip of stylus 142  
30 can be rigidly or rotatably attached to alternative base 140' with, for example, a ball joint or other joint or fastener.

In Fig. 5c, another alternative base 140'' is provided with an enlarged aperture 144' which can be engaged by the tip of a finger 146 of the user. The base 140'' then becomes the user manipulatable object 76c. As before, the base 140'' is coupled the flexible members 134 and 138 of  
35 the first feedback device 50b of Fig. 5a.

The embodiments of figures 5b and 5c illustrate two of a range of equivalent user manipulatable objects suitable for the present invention. It should be apparent to those skilled in the art that these alternative objects 76b of Fig. 5b and 76c of Fig. 5c can equally well be used with other force feedback devices, such as the force feedback device 50a illustrated in Fig. 4a.

5 As noted previously, a preferred embodiment of the present invention provides a user manipulatable object that has two degrees of freedom. Other user manipulatable objects having one degree of freedom or three or more degrees of freedom are also within the scope of the present invention. For example, one embodiment of the present invention provides only one degree of freedom. Other force feedback devices of the present invention include mice, joysticks, joypads, a  
10 steering wheel, and yolks having two or more degrees of freedom.

In Fig. 6, a conceptual representation of the network system 10 with force feedback includes a server machine 18, a client machine 14 provided with a force feedback device 24, and one or more additional client machines 16, each of which may be provided with additional force feedback devices 26. As noted in this figure, the server machine is a computer or "processor" running, for example,  
15 the TCP/IP server software and is which is connected to the Internet. The client machine 14 includes a computer or "processor" running Internet browser software and force feedback driver software. The processor of the client machine is connected to the Internet and to the force feedback device 24. The force feedback device 24 has sensors and actuators so that it can track movement of the user manipulatable object, monitor for button presses and/or other ancillary input devices, and provide  
20 output force feedback sensations. The force feedback device 24 sends object tracking information to the client machine, and receives force feedback commands from the client machine 14. The "additional client", such as client machine 16, also includes computers or "processors" running Internet browser software and force feedback driver software. The processors of these additional clients are also connected to the Internet and are connected to force feedback devices associated with  
25 that client.

As noted in Fig. 6, a client machine 14 can send a data request to the server machine 18 and, in return, receive an HTML web page file including a special file of the present invention known as an "IFF" file. As will be appreciated by those skilled in the art, the server must also have a modified configuration file which lets it know that .IFF is a valid MIME type. This modified file would be a  
30 SRM.CONF or other .CONF file. The client machine 14 then sends force feedback commands to the force feedback device 24 and receives tracking and button data from the force feedback device 24. Client machine 16 can likewise send a data request to the server machine 18 and receive an HTML file with one or more IFF files. The client machine 16 can then interact with the force feedback device 26 by sending force feedback commands to the device 26 and by receiving tracking and button  
35 data from the force feedback device 26.

In addition to communicating with the server machine, the client machines can communicate directly with each other over the Internet using an Internet communication protocol. For example, client machine 14 can communicate with client machine 16 through a TCP/IP connection. This is accomplished making the URL of the client machine 16 known to the client machine 14, and vice  
40 versa. In this fashion, direct communication between client machines can be accomplished without involving the server machine 18. These connections can send force feedback information and other

5 information to the other client machine. For example, a process on the client machine 16 can send force feedback information over a TCP/IP Internet connection to the client machine 14, which will then generate a force feedback command to the force feedback device 24. When the user reacts to the force feedback at force feedback device 24, this information can be sent from client machine 14 to client machine 16 to provide force feedback to the user on force feedback device 26.

10 In Fig. 7a, a flow diagram illustrates an "acquire URL" process 146 running on a client machine, such as client machine 14 or client machine 16. This process 146 is preferably implemented using a standard Internet browser with a "plug-in" extension which permit the handling of force feedback commands. A preferred browser software is Netscape Navigator<sup>®</sup> software available from Netscape Corporation of Mountain View, California. The plug-in software is a  
15 proprietary extension of the web browser software, where this proprietary extension was developed by the Applicant of the present application.

The process 146 begins at 148 and, in a step 150, a connection request is sent to the "host" of the desired URL. The host, in this example, is a server machine 18 and the desired URL is the URL of the desired web page residing on the server machine 18, the web page including force feedback  
20 commands. Alternatively, the desired web page can reside on another server or resource and be retrieved by server machine 18. In response to the connection request of step 150, the server machine 18 sends the HTML file representing the web page over the Internet to be received by the client machine. The HTML file includes a number of "components" which are typically commands, command fragments, instructions, and data which permit the display of the web page and other web  
25 browser functionality. In a step 154, an HTML component is obtained. If this component is the end of file ("eof"), a step 156 detects that fact and the process is completed at 158. Otherwise, the HTML component is parsed and interpreted at a step 160 and process control is returned at step 154.

It should be noted that most web browser software will start parsing and interpreting (*i.e.* processing) the HTML components even before the entire HTML file is received at the client  
30 machine. Alternatively, the entire HTML file can be received before the processing begins.

In Fig. 7b, an example of an HTML web page 32, sent from a web server machine 18 to a client machine (such as client machine 14 or 16) over the Internet 12, is shown. The HTML file 32 includes a number of "components" which are parsed and interpreted as previously described. An HTML file begins with a <HTML>command 162 to indicate the start of the HTML file, and a  
35 <BODY> command 164 to indicate that the body of the HTML file is beginning. Then, an arbitrary number of HTML commands 166 are provided to, for example, display images of the web page on the video display of the client machine. A <CENTER> command 168 will cause a centering of following objects with respect to the browser window on the video display of the client machine. Next, an <EMBED ...> command 170 of the present invention defines a force button object that will  
40 be displayed on the client machine. Since the <CENTER> command 168 was given just prior to the <EMBED ...> command, this "force button" will be centered in the displayed browser window.



5       The present invention also provides for programmability of the embedded force feedback object. An example of this programmability is shown at 198. This optional programmable command can be inserted into the **EMBED** command 170 and can include, for example, an iterative loop. In line 200, a "FOR" command initializes a counter *i* to 0, indicates that the counter *i* is incremented by one per each pass through the loop, and it indicates that the loop should be completed five times, *i.e.* while *i* < 5. The body of the loop includes a command line 202 which indicates that a force feedback "vibrate" with associated parameters should be evoked, and a line 204 indicates that a 5 second wait should be provided after the vibration has occurred. This step will repeat five times, *i.e.* the command 198 will cause five vibration sequences separated by four 5 second pauses, and followed by a final 5 second pause. By providing programmability to the force feedback object, force feedback effects based upon past events and upon a complex interaction of factors can be provided.

10       In Fig. 8, the "Parse And Interpret HTML Component" or simply "Process HTML Component" step 160 of Fig. 7a is illustrated in greater detail. In Fig. 8, process 160 begins at 206 and, in a step 208, it is determined whether there is an embedded "tag" for a force object, *e.g.* a tag having an .IFF reference. An example of the embedded tag is shown at the **EMBED** command 170 of Fig. 7b. If there is such a tag, step 210 uses the plug-in software of the present invention to interpret the .IFF file, and the process is completed at 212. Otherwise, another type of HTML command has been encountered, and the standard web browser parser and interpreter processes this HTML component in a step 214, after which the process is completed at 212.

15       In Fig. 9, the step 210 "Plug-In Interprets .IFF File" of Fig. 8 is described in greater detail. Process 210 begins at 216, and in a step 218, a "framework" is created for the force object. The framework provides a particular set of generic features to implement the specified force object, and preferably includes no specific parameters or functions for the force object. Next, in a step 220, the name/value pairs are parsed and, in a step 222, the force object is built upon this framework based upon the name/value pairs. A name/value pair includes the name of a component and its associated parameters. For example, one name might be "BUTTONSTATE" and its value (or parameter) might be "UP" (or "UNSELECTED"). The process 210 is completed at 224.

20       In Fig. 9a, an image 226 to be displayed on a screen of a video monitor or other visual display is illustrated. More specifically, image 226 can be generated by the popular Netscape Navigator<sup>®</sup> web browser. The image 226 includes a window 228 including a header portion 230 and a body portion 232. The header portion 230 includes a number of navigation buttons 234 and special purpose buttons 236 for purposes well-known to those familiar with the Netscape Navigator web browser. In addition, the header portion 230 displays the URL of the currently displayed web page at 238. In this instance, the URL is "http://www.immerse.com/demo." The images displayed within the body portion 232 of the window 228 are created by the aforementioned processing of the HTML file by the web browser.

- 5 Other force objects besides button objects can also be defined and displayed, such as links, text, sliders, game objects (balls, paddles, etc.), avatars, windows, icons, menu bars, drop-down menus, or other objects.

10 In a first line 172 of the `<EMBED ...>` command, the force button object is defined by a "IFF" extension file, namely "FORCEBUTTON.IFF." Next, in a line 174, the size of the button is indicated to be 100 pixels by 100 pixels. In a line 176, the initial state of the button is indicated to be "up" (i.e., unselected), and a line 178 defines the force effect to be "vibration." A number of parameters 180 defining the character and nature of the vibration are also provided (start time, length, frequency, magnitude, etc.). In a line 182, the "trigger" for the force effect is given by the function "MOUSEWITHIN" with its associated parameters, and by the function "BUTTONSTATE." The  
15 function MOUSEWITHIN determines whether the pointer icon, the position of which is controlled by the force feedback device, is within the specified boundaries defining a region of the force button. This region can be specified by the parameters and, for example, can be defined as the exact displayed area of the button, or can be defined as a sub-region within the button that is smaller than the displayed size of the button. The function BUTTONSTATE determines whether a button or  
20 switch of the force feedback device is in the desired state to trigger the force object event (e.g., a button event in this example). In a line 184, the icon representing the force button is specified as "LOUIS.GIF," and the text associated with the button is defined as "Hi, I'm Louis" in a line 186. The font of the text is given as "Helvetica" in a line 188. Other force effects, triggers and parameters can also be associated with the force object. For example, a force (such as a vibration) can be  
25 triggered if the pointing icon is moved a predetermined velocity or within a predefined range of velocities within the force object. Or, a trajectory of the pointing icon on a force object can trigger a force, like a circle gesture.

The `<EMBED ...>` command is an existing functionality of HTML. It essentially embeds function calls which are handled by the web browser. If the suffix of the specified file is a known,  
30 standard suffix type, the call is executed directly by the web browser. If, however, the suffix (.IFF in this instance) is not a standard feature of the web browser, the browser will first look for a "plug-in" to implement this feature and, if a suitable plug-in is not found, it will look for application programs implementing this feature. In the preferred embodiment of the present invention, a plug-in including a reference to a Dynamically Linked Library (DLL) is provided to give functionality to the  
35 .IFF suffix. The DLL can be provided local to the client machine or on another linked resource.

With continuing reference to Fig. 7b, the centering command is terminated at line 190 with the `</CENTER>` command. Additional HTML commands 192 can then be provided, and the body of the HTML file is terminated by the `</BODY>` command 194. The end of the HTML file is indicated at 196 with the `</HTML>` command, i.e. this command 196 is the "eof" command of the  
40 HTML file 32.

5       The area within the body portion 232 has been provided with a number of regions and buttons to illustrate some of the concepts of the present invention. The force feedback device controls the position of a pointer icon 240 which can be caused to interact with the various regions and buttons. As an example, when the force feedback device is manipulated by the user to cause the pointer icon 240 to move within a "texture" region 242, force feedback commands can be created for  
10       the force feedback device to provide a desired "texture" to the force feedback device. For example, the texture can feel "rough" to the user by causing the force feedback device to place forces on the user manipulatable object that emulate a rough or bumpy surface. In a region 244, a "viscosity" force feedback can be provided. With this form of force feedback, as the pointer icon is moved through field 244, a viscous "drag" force is emulated on the user manipulatable object. In a region  
15       246, inertial forces can be felt. Therefore, a pointer icon being moved through an "inertia" region would require relatively little or no force to move in a straight line, but would require greater forces to accelerate in a new direction or to be stopped. The inertial force sensations can be applied to the user manipulatable object and felt by the user. In a "keep out" region 248, the pointer image is prevented from entering the region. This is accomplished by creating a repulsive force on the user  
20       manipulatable object using a force feedback command to the force feedback device which prevents or inhibits the user from moving the user manipulatable object in a direction of the region 248 when the pointer icon 240 contacts the periphery of the region 248. In contrast, a "snap-in" region 250 will pull a pointer icon 240 to a center 252 whenever the pointer icon engages the periphery of the snap-in region 250 and apply a corresponding attractive force on the user manipulatable object. A "spring"  
25       region 243 emulates a spring function such that a pointer icon moving into the spring region "compresses" a spring, which exerts a spring force on the user manipulatable object which opposes the movement of the pointer icon. A region 256 is a "Force To Left" region where the pointer icon within the region 256 is forced to the left side of the region and the user manipulatable object is forced in a corresponding direction as if influenced by some invisible magnetic force or gravitational  
30       force. A region 258 illustrates that regions can be of any size or shape and that within a region different force effects can be developed. In this example, within region 258 there is a texture core 260 surrounded by a vibration ring 262. Therefore, as the pointer icon 240 moves into the region 258, the user first experiences vibration from the ring 262, and then experiences a texture as the pointer icon moves within the core 260.

35       The exemplary force feedback web page of Fig. 9a is also provided with several force feedback buttons. In a first button 264, the placement of the pointer icon 240 over the button and the pressing of a button (*i.e.*, a switch) on the force feedback device to create a "button click", "button down", or simply a "button event" input, will then cause a "buzz" command to be sent to the force feedback device. The buzz command would, for example, cause a vibration force on the user  
40       manipulatable object. Similarly, the selection of the "jolt" button 266 will cause a jolting force (*e.g.*, a short-duration pulse of force) to be provided at the force feedback device, and the pressing of the "detent" button 268 will cause a "detent" to be created for the force feedback device. By "detent" it is meant that the user manipulatable object will be controlled by the force feedback actuators such that it

5 feels as if a mechanical-type detent exists at the position that the user manipulatable object was in when the detent button 268 was activated.

In Fig. 10, a process 270 of the plug-in software of the present invention is illustrated. The process 270 begins at 272 and, in a step 274, the position and button state of the force feedback device is monitored. Next, in a step 276, a force feedback command is created in response to the  
10 detected position and state. Finally, a command is sent to the Dynamically Linked Library (DLL) to place a force feedback command on the interface which can be parsed and interpreted by the force feedback device. The process is then completed as indicated at 280.

It should be noted that the force feedback driver (browser plug-in or DLL) can have the ability to interact with JAVA code. In this embodiment, the plug-in reads and executes JAVA  
15 commands using the browser's run-time JAVA interpreter. JAVA can optionally be used to make "applets" which perform dynamic models, such as creating complex force feedback sensations.

It should also be noted that the force feedback device itself can have a JAVA interpreting chip on board, permitting the plug-in driver to download JAVA code to the force feedback device to be executed on the device. JAVA and JAVA interpreting chips are available under license from SUN  
20 Microcomputers of Mountain View, California.

Furthermore, the force feedback driver (browser plug-in or DLL) can have the ability to interact with instructions provided in other languages besides HTML. For example, virtual reality 3-D graphical environments are increasingly being created and implemented over the World Wide Web and Internet using languages such as the Virtual Reality Modeling Language (VRML) and software  
25 such as Active X available from Microsoft Corporation. In these 3-D graphical environments, users may interact with programmed 3-D objects and constructs using client computer 14 or 16, and may also interact with 3-D graphical representations (or "avatars") controlled by other users over the World Wide Web/Internet from other client computers. Force feedback commands and parameters can be provided in the instructions or files of these other protocols and languages and received by a  
30 client computer system in an equivalent manner to that described above so that force feedback can be experienced in simulated 3-D space. For example, embedded force feedback routines can be included in the VRML data for a virtual environment so that when the user moves into a virtual wall, an obstruction force is generated on the user-manipulatable object. Or, when the user carries a virtual object in a controlled virtual glove, the user might feel a simulated weight of the virtual object on the  
35 user manipulatable object. In such an embodiment, the force feedback device preferably provides the user with three or more degrees of freedom of movement so that input in three dimensions can be provided to the client computer.

While this invention has been described in terms of several preferred embodiments, there are alterations, permutations, and equivalents which fall within the scope of this invention. It should  
40 also be noted that there are many alternative ways of implementing both the process and apparatus of the present invention. It is therefore intended that the following appended claims be interpreted as

- 5 including all such alterations, permutations, and equivalents as fall within the true spirit and scope of the present invention.

5

C L A I M S

1. A method for providing force feedback over a network comprising:
  - establishing a connection between a server machine and a client machine over a network, said client machine including a visual display and a human/computer interface device having force
  - 10 feedback;
  - receiving from said server machine over said network screen display information and force feedback information related to said screen display information;
  - displaying on said visual display of said client machine a screen image based upon said screen display information;
  - 15 providing a pointer event with said human/computer interface device with respect to said screen image;
  - computing a force feedback signal based upon said pointer event; and
  - providing a force feedback with said human/computer interface device based upon said force-feedback signal that is correlated to said screen image on said visual display.
  - 20
2. A method for providing force feedback over a network as recited in claim 1 wherein said server machine is a web server, said client machine is a network access computer.
3. A method for providing force feedback over a network as recited in claim 2 wherein
- 25 said web server and said network access computer communicate over said network using TCP/IP protocols.
4. A method for providing force feedback over a network as recited in claim 2 wherein
- 30 said pointer event is at least one of a pointer icon movement on said visual display with respect to said screen image and a button click of said human/computer interface device.
5. A method for providing force feedback over a network as recited in claim 3 wherein said human/computer interface device has at least two degrees of freedom.

5           6.     A method for providing force feedback over a network as recited in claim 5 wherein said human/computer interface device includes a voice coil actuator for providing at least a portion of said force feedback.

7           A method for providing force feedback over a network as recited in claim 5 wherein  
10   said human/computer interface has exactly two degrees of freedom.

8.     A method for providing force feedback over a network as recited in claim 5 wherein said human/computer interface is provided with a local microprocessor which communicates with said network access computer, said human/computer interface including sensors and actuators  
15   coupled to said local microprocessor, and wherein said force-feedback signal is a force feedback command, said method further comprising:

        parsing said force feedback command on said local microprocessor to control said actuators of said human/computer interface in a control loop with said sensors of said human/computer interface.

20

9.     A method for providing force feedback over a network as recited in claim 5 further comprising:

        developing on said server machine an HTML file including said screen display information and said force-feedback information.

25

10.    A method for providing force feedback over a network as recited in claim 9 wherein said HTML file includes an embedded reference that can be used to create a force feedback object on said client machine, and further comprising:

        parsing on said client machine said HTML file and creating on said client machine said force  
30   feedback object.

11.    A method for providing force feedback over a network as recited in claim 5 further comprising:

        developing on said server machine an VRML file including said screen display information  
35   and said force-feedback information.

5           12.     A method for providing force feedback over a network as recited in claim 10 wherein said computing a force feedback signal includes:

                  monitoring for a pointer event from said human/computer interface; and

                  using said force feedback object and said pointer event to provide said force feedback signal.

10           13.     A method for providing force feedback over a network as recited in claim 1, wherein said client machine is a first client machine, and further comprising a second client machine coupled to said network, said second client machine including a visual display and a human/computer interface capable of providing a pointer event, said method further comprising:

                  establishing a connection between said first client machine and said second client machine  
15     over said network;

                  receiving at said first client machine second client information from said second client machine;

                  computing a force feedback signal based upon said second client information; and

                  providing a force feedback with said human/computer interface device based upon said force  
20     feedback signal.

                  14.     A method for providing force feedback over a network as recited in claim 13 wherein said server machine is a web server, said first client machine is a network access computer, said second client machine is a network access computer, and said web server, said first network access  
25     computer, and said second network access computer can communicate with said network using TCP/IP protocols.

                  15.     A method for providing force feedback over a network as recited in claim 14 wherein said pointer event is at least one of a pointer icon movement on said visual display of said first  
30     network access computer with respect to said screen image and a button click of a human/computer interface device of at least one of said first network access computer and said second network access computer.

                  16.     A method for providing force feedback over a network as recited in claim 15 wherein  
35     said human/computer interface devices of said first network access computer and said second network access computer each have at least two degrees of freedom.



5

17. A method for providing force feedback over a network as recited in claim 16 wherein said human/computer interface devices each have exactly two degrees of freedom.

18. A method for providing force feedback over a network as recited in claim 17 wherein  
10 said human/computer interface devices each include a voice coil actuator for providing at least a portion of said force feedback.

19. A method for providing force feedback over a network comprising:  
15 establishing a connection between a first computer and a second computer over a network, where said first computer includes a computer input device providing a first computer input, and wherein said second computer includes a visual display and a human/computer interface device providing force-feedback in response to a force feedback signal and providing a second computer input;  
20 displaying on said monitor of said second computer a screen image that is associated with stored force feedback information;  
receiving from said first computer over said network a first computer input associated with said screen image on said second computer;  
determining said force feedback signal based upon said stored force feedback information,  
25 and at least one of said first computer input and said second computer input; and  
providing a force feedback with said human/computer interface device in response to said force feedback signal that is correlated to said screen image on said second computer.

20. A method for providing force feedback over a network as recited in claim 19 wherein  
30 said first computer and said second computer communicate over said network using TCP/IP protocols.

21. A method for providing force feedback over a network as recited in claim 19 wherein  
35 establishing a connection includes the exchange of URLs between said first computer and said second computer.

5           22.     A method for providing force feedback over a network as recited in claim 19 wherein said first computer input and said second computer input comprise a pointer event including at least one of a pointer movement and a button click.

10           23.     A method for providing force feedback over a network supporting TCP/IP protocols comprising:

          sending from a client computer over a network supporting TCP/IP protocols a connection request to a web server connected to said network that is hosting a desired URL;

          receiving and parsing an HTML file at said client computer that was sent from said web server in response to said connection request, wherein said parsing includes parsing an embedded  
15   force object reference having associated parameters and building a force object as specified by said force object reference and said associated parameters;

          developing a force feedback signal with said force object; and

          providing force feedback to a human/computer interface device coupled to said client computer in response to said force feedback signal.

20

          24.     A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 23 wherein said HTML file comprises a web page of said web server.

25           25.     A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 24 wherein a network browser is provided on said client computer to perform said parsing and developing said force feedback signal.

30           26.     A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 25 wherein said network browser is provided with a plug-in to aid in the parsing of said embedded force object reference, building said force object, and developing said force feedback signal.

35           27.     A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 26 wherein said human/computer interface device is provided with a local microprocessor that communicates with said client computer, and wherein said force feedback signal is a force feedback command sent from said client computer to said human/computer interface device.

5

28. A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 27 wherein said local microprocessor can interpret JAVA instructions sent from said client computer.

10

29. A method for providing force feedback over a network supporting TCP/IP protocols as recited in claim 27 wherein said human/computer interface device includes actuators and sensors, and further comprising:

parsing on said local microprocessor said force feedback command to control said actuators in a feedback loop with said sensors.

15

30. A networked force feedback system comprising:

a network;

a first computer coupled to said network; and

20 a second computer coupled to said network, said second computer including a visual display and a human/computer interface device capable of providing a second computer input and capable of providing force feedback in response to a force feedback signal provided by said second computer, said second computer developing an image on said visual display that is associated with stored feedback information, wherein said second computer produces said force feedback signal in response to at least one of information derived from said first computer and of said second computer input.

25

31. A networked force feedback system as recited in claim 30 wherein said first computer is a server computer, said second computer is a network access computer, and wherein said information derived from said first computer includes screen display information and force feedback information related to said screen display information.

30

32. A networked force feedback system as recited in claim 31 wherein said information derived from said server computer is sent from the server computer to the network access computer in the form of an HTML file.

35

33. A networked force feedback system as recited in claim 31 wherein said information derived from said server computer is sent from the server computer to the network access computer in the form of a VRML file.

5

34. A networked force feedback system as recited in claim 30 wherein both said first computer and said second computer are network access computers which communicate over said network using TCP/IP protocols.

10

35. A networked force feedback system as recited in claim 34 wherein said information derived from said first computer includes information that affects the force feedback signal.

15

36. A networked force feedback system as recited in claim 35 wherein said information derived from said first computer and said second computer input both comprise at least one of a pointer icon position input and a button click input.

20

37. A networked force feedback system as recited in claim 30 wherein said human/computer interface device coupled to said second computer includes a local microprocessor that communicates with said second computer, a plurality of actuators for providing a force feedback, and a plurality of sensors for sensing positions of said human/computer interface device.

25

38. A networked force feedback system as recited in claim 37 wherein said human/computer interface device coupled to said second computer includes a base for receiving input from said user, said base being movable in two linear degrees of freedom.

39. A networked force feedback system as recited in claim 38 wherein said base is receptive to a finger of said user for manipulating said base in said two linear degrees of freedom.

30

40. A networked force feedback system as recited in claim 38 wherein said base is receptive to a stylus for manipulating said base in said two linear degrees of freedom.

35

41. A networked force feedback system as recited in claim 37 wherein said force feedback signal includes a force feedback command that can be parsed by said local microprocessor such that said microprocessor can control said actuators in response to said force feedback command in a control loop with said sensors.

5           42.    A networked force feedback system comprising:  
              network means;  
              first computer means coupled to said network means; and  
              second computer means coupled to said network means, said second computer means  
              including visual display and human/computer interface means, said second computer means further  
10       including means for displaying an image on said visual display that is associated with stored force  
              feedback information of said second computer means, said second computer means further including  
              means for analyzing information sent to said second computer means from said first computer means  
              over said network means, said second computer means further including means for developing a  
              force feedback at said human/computer interface means using said stored force feedback information  
15       in response to at least one of said information sent by said first computer means and a second  
              computer input providing by said human/computer interface means.

              43.    A networked force feedback system as recited in claim 42 wherein said first computer  
              means is a server computer means, said second computer means is a network access computer  
20       means, and wherein said information derived from said first computer means includes screen display-  
              information and force feedback information related to said screen display information.

              44.    A networked force feedback system as recited in claim 43 wherein said information  
              derived from said server computer means is sent from the server computer means to the network  
25       access computer means in the form of an HTML file.

              45.    A networked force feedback system as recited in claim 42 wherein both said first  
              computer means and said second computer means are network access computer means which  
              communicate over said network using TCP/IP protocols.

30           46.    A networked force feedback system as recited in claim 45 wherein said information  
              derived from said first computer means includes information that affects said force feedback signal.

              47.    A networked force feedback system as recited in claim 46 wherein said information  
35       derived from said first computer means and said second computer means input both comprise at least  
              one of a pointer icon position input and a button click input.

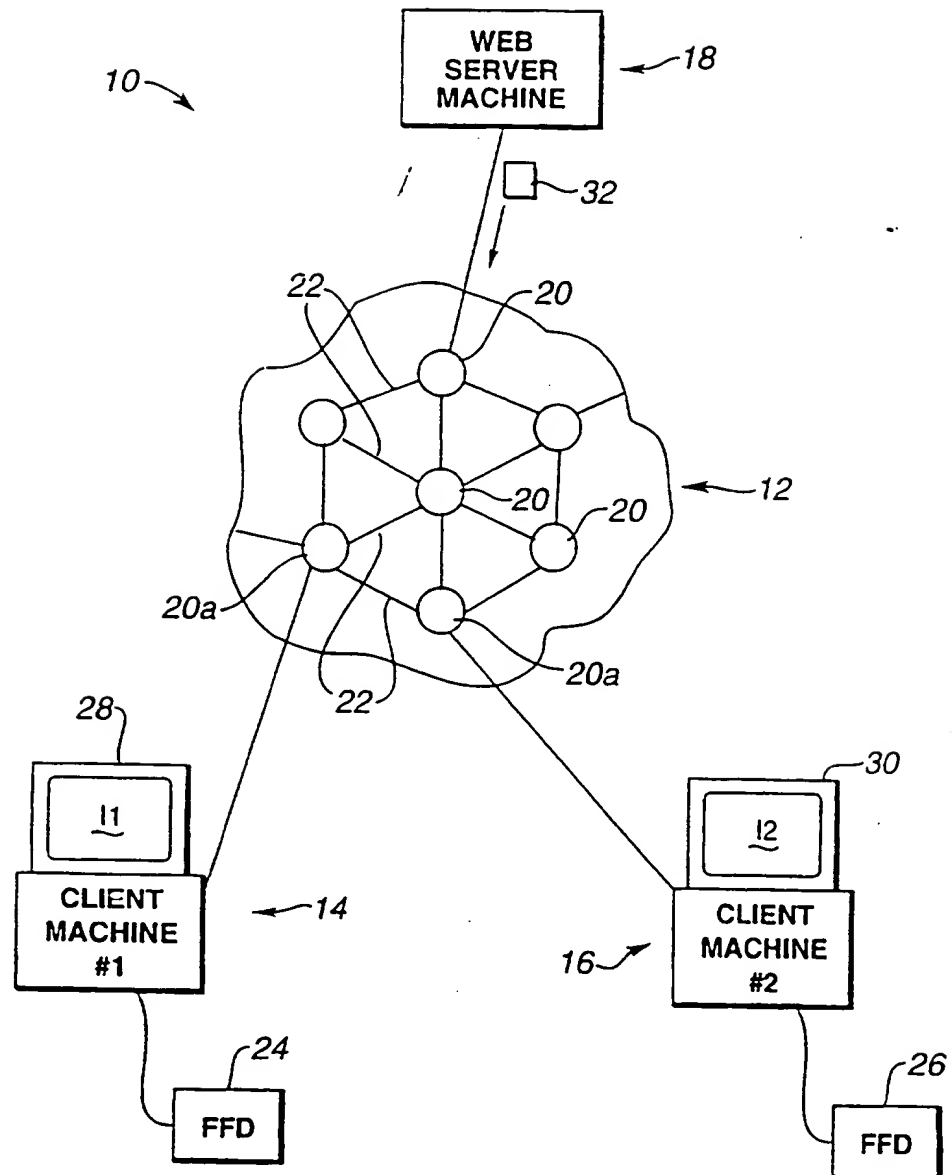
5           48. A networked force feedback system as recited in claim 42 wherein said human/computer means interface device coupled to said second computer means includes a local microprocessor means that communicates with said second computer means, a plurality of actuator means for providing a force feedback, and a plurality of sensor means for sensing positions of said human/computer means interface device.

10

          49. A networked force feedback system as recited in claim 48 wherein said force feedback signal includes a force feedback command that can be parsed by said local microprocessor means such that said microprocessor means can control said actuator means in response to said force feedback command in a control loop with said sensor means.

15

1/10

*Figure 1*

2/10

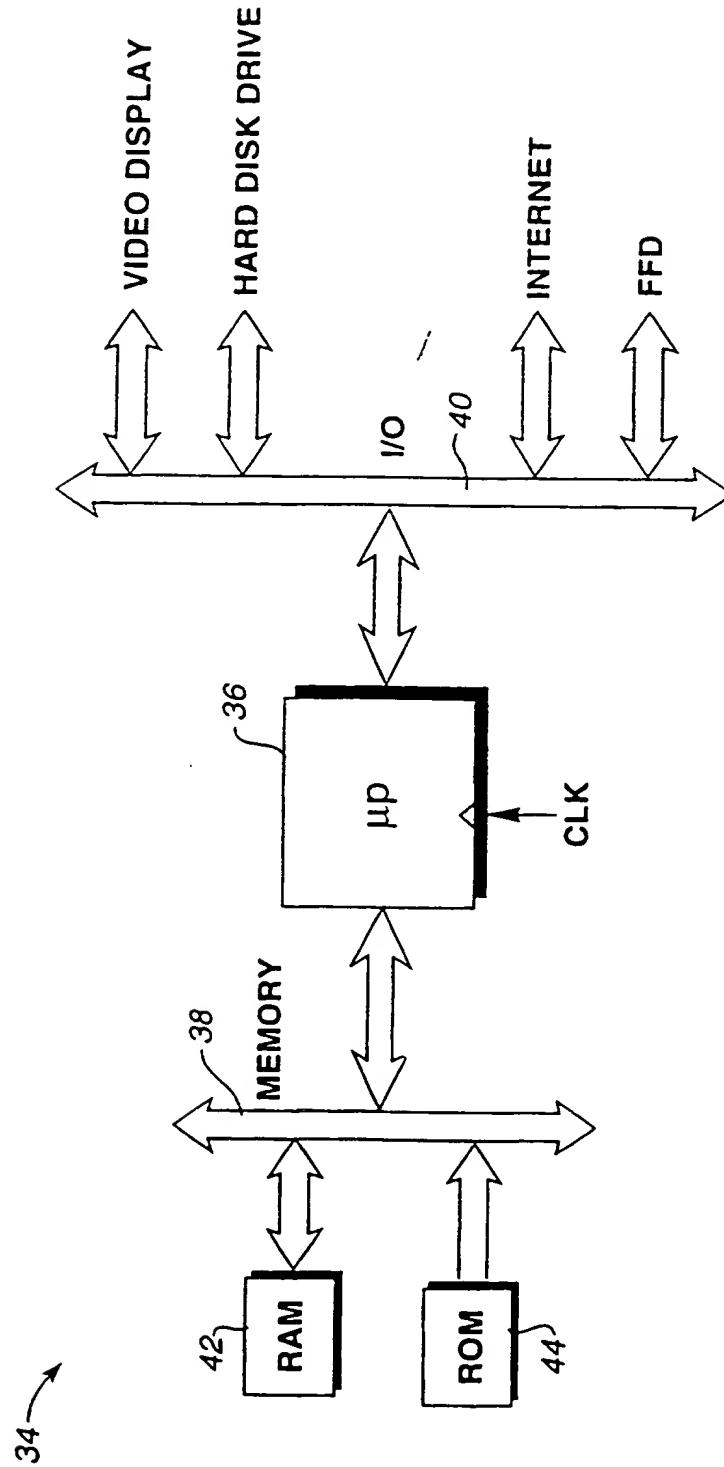


Figure 2



3/10

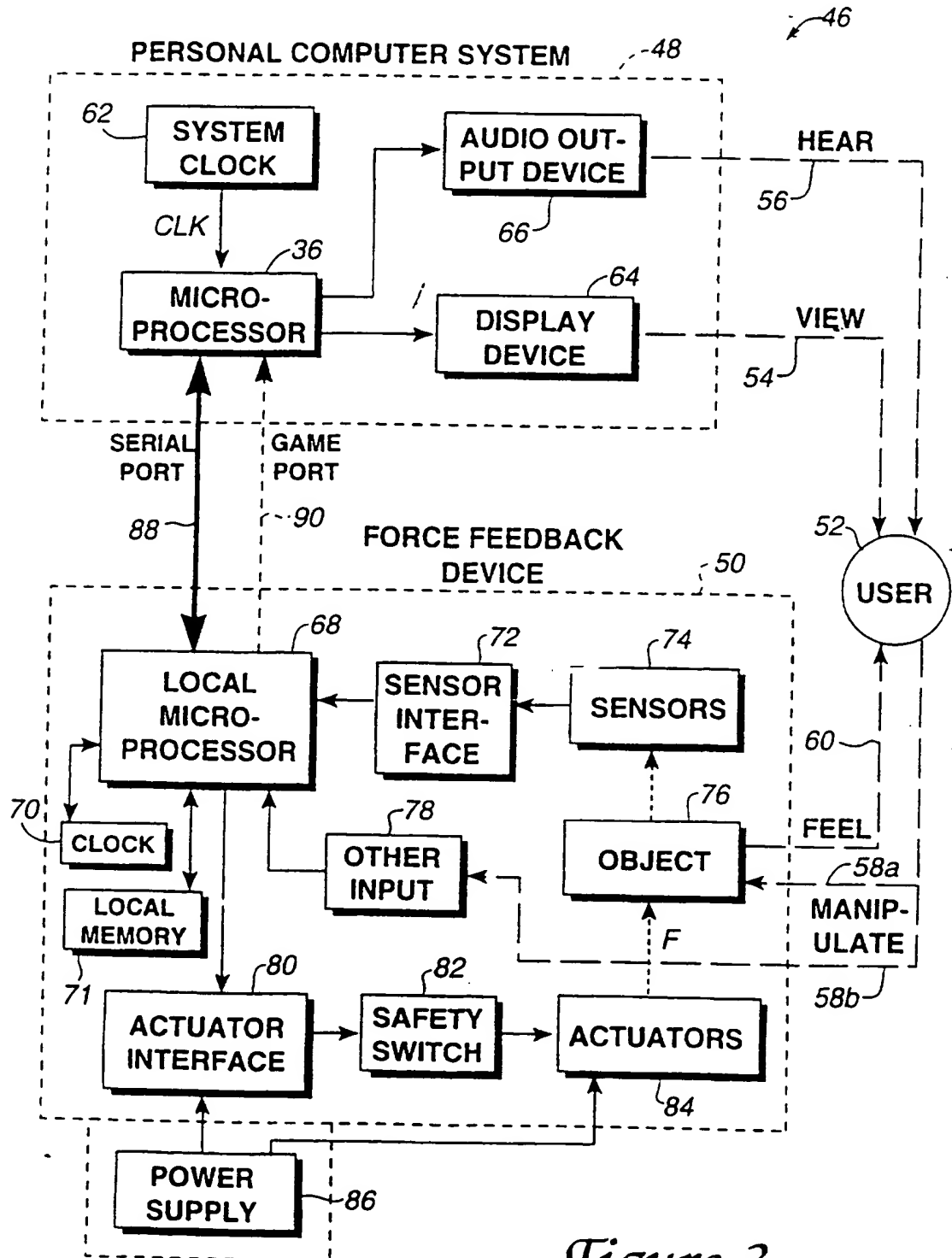
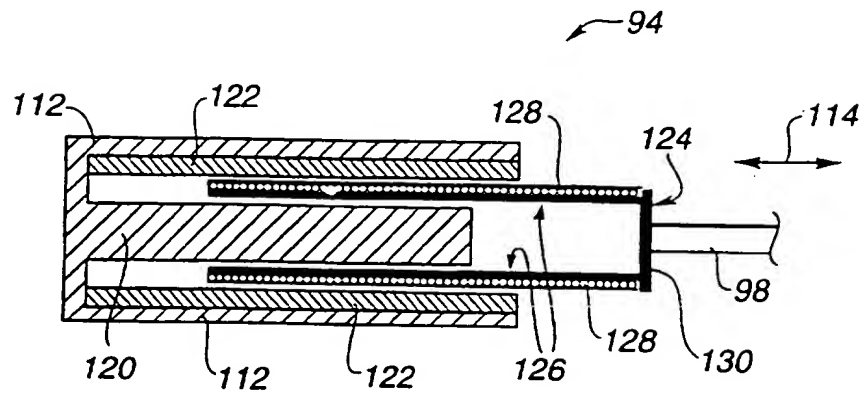
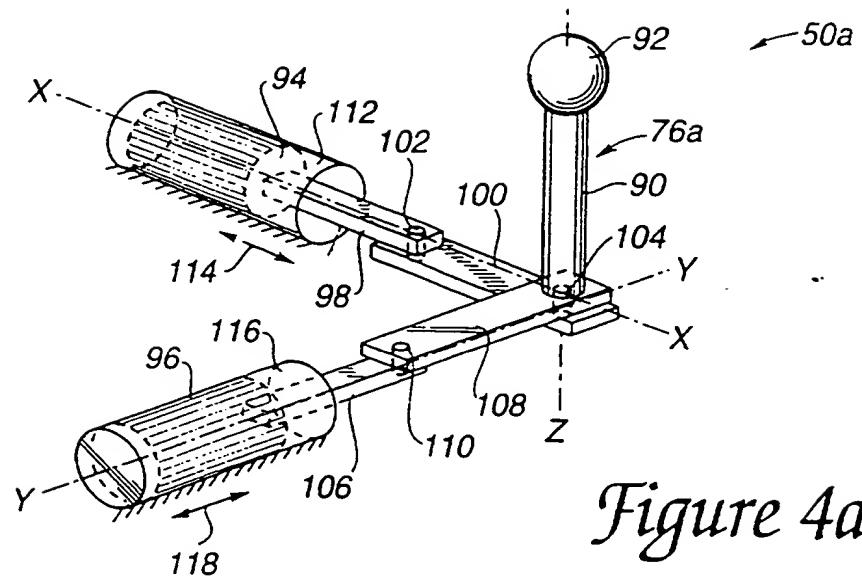
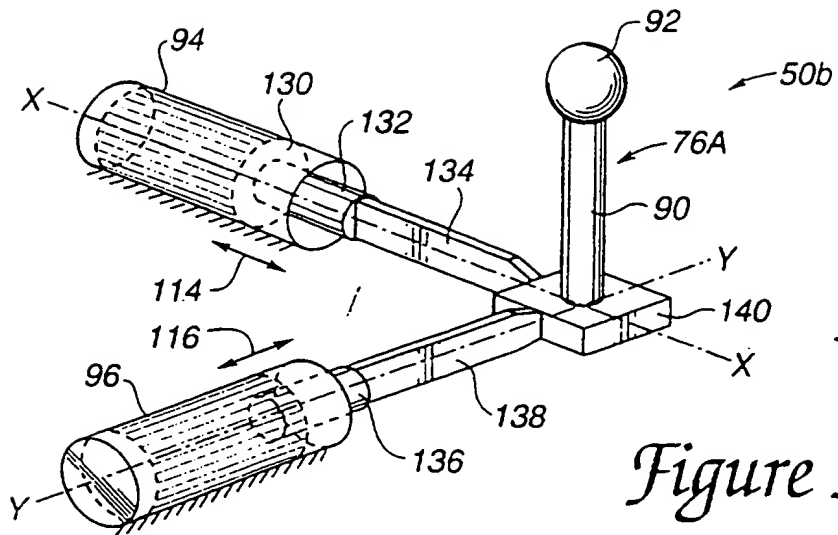


Figure 3

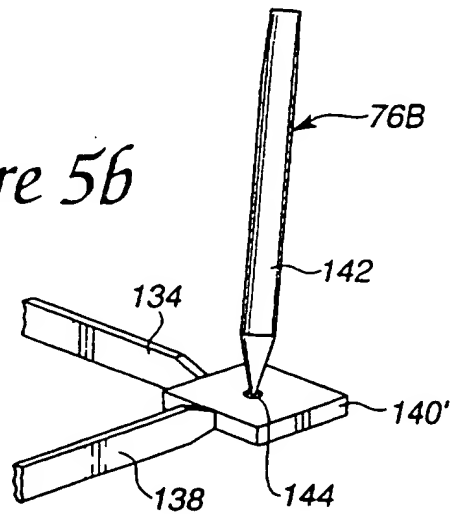
4/10



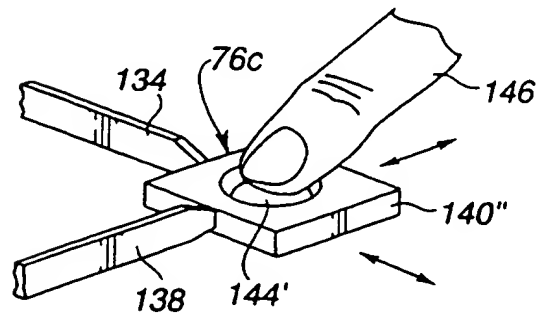
5/10



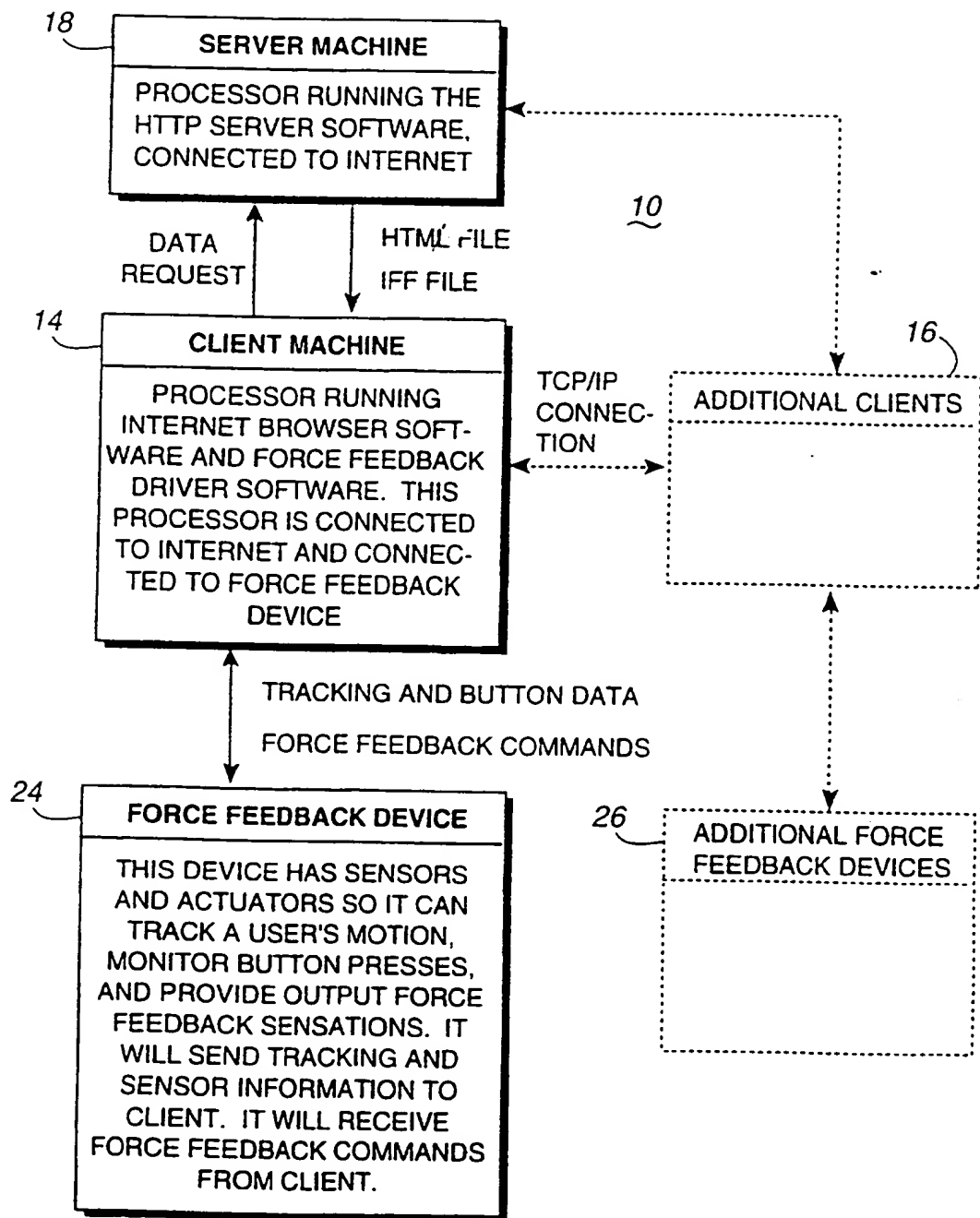
*Figure 5b*



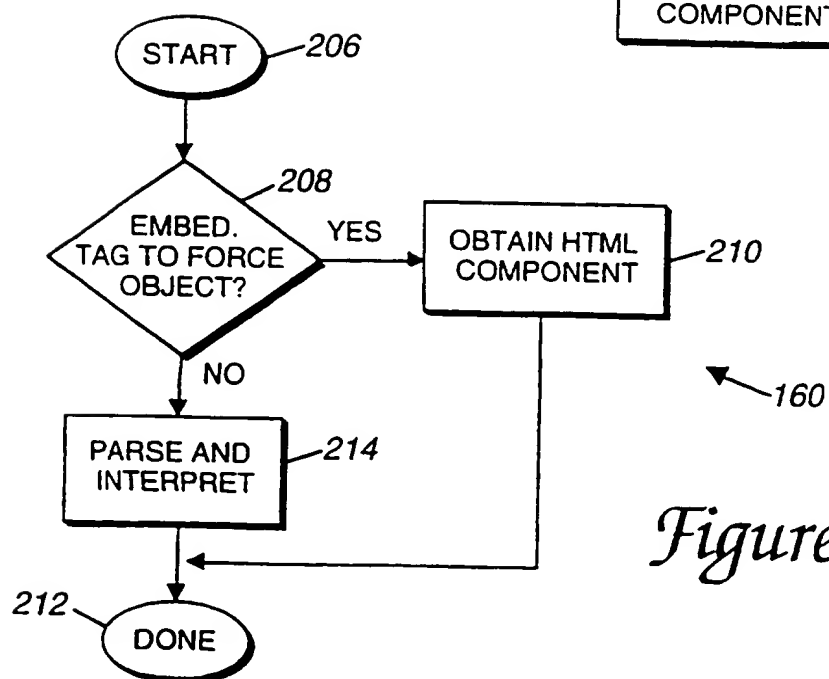
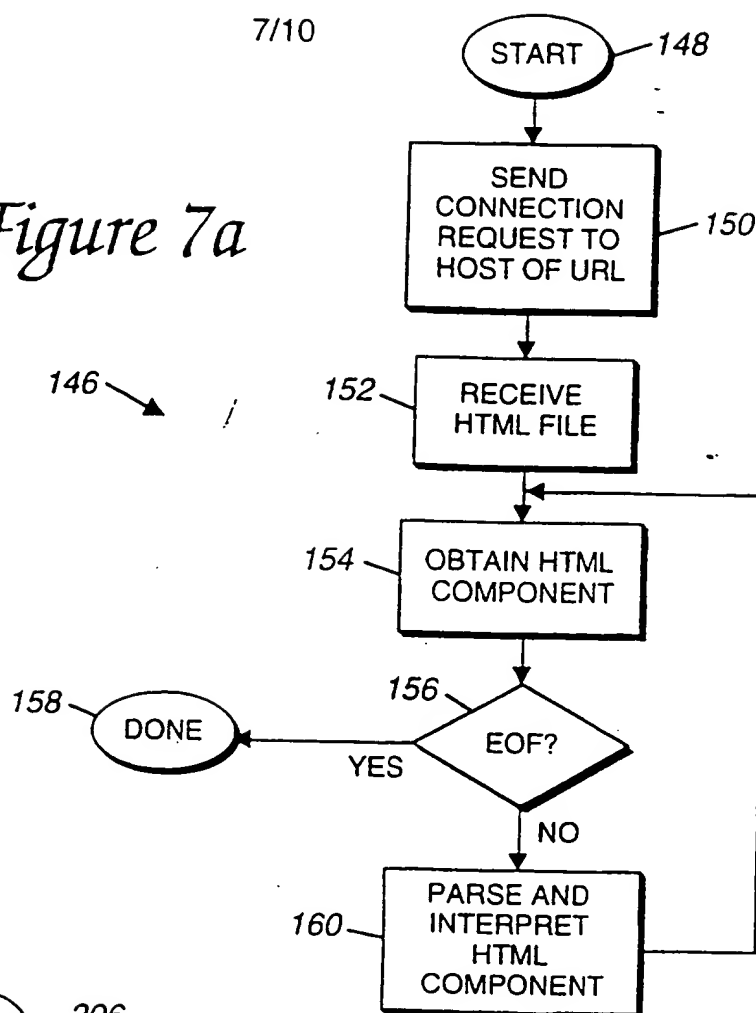
*Figure 5c*



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*Figure 6*

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*Figure 7a**Figure 8*

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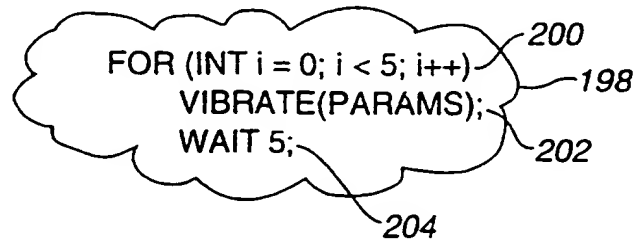
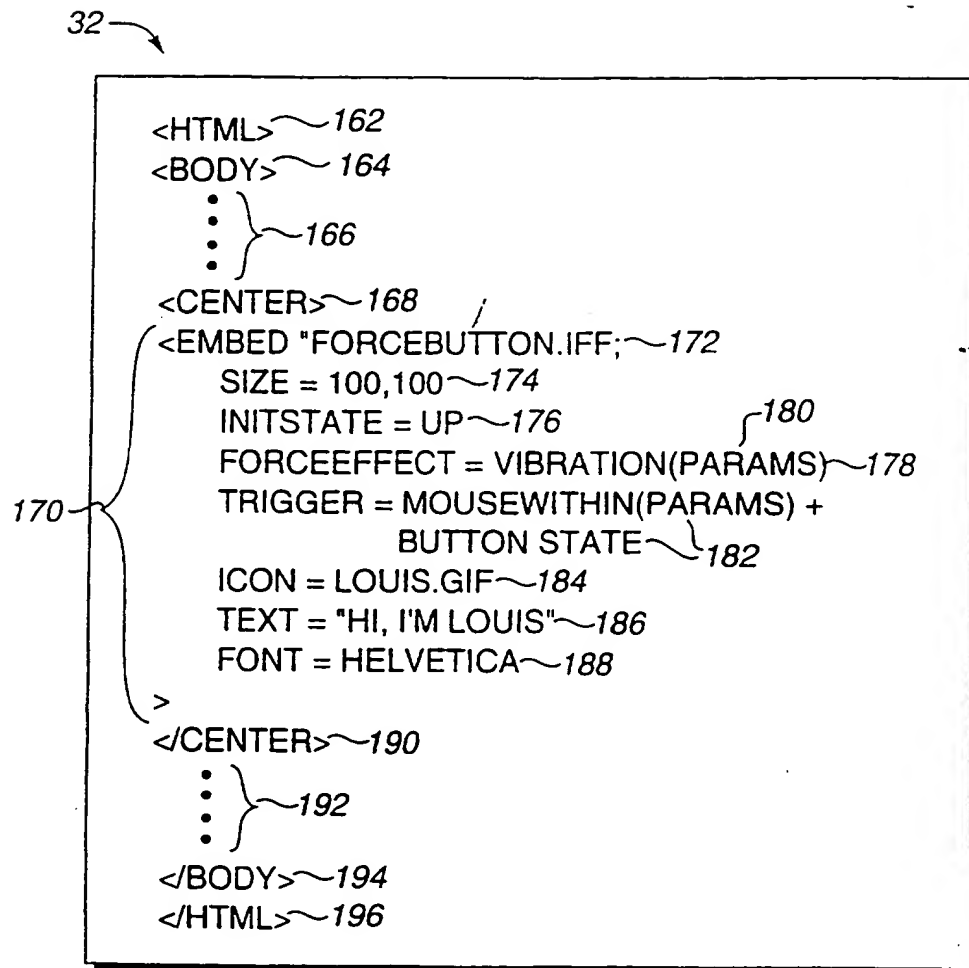
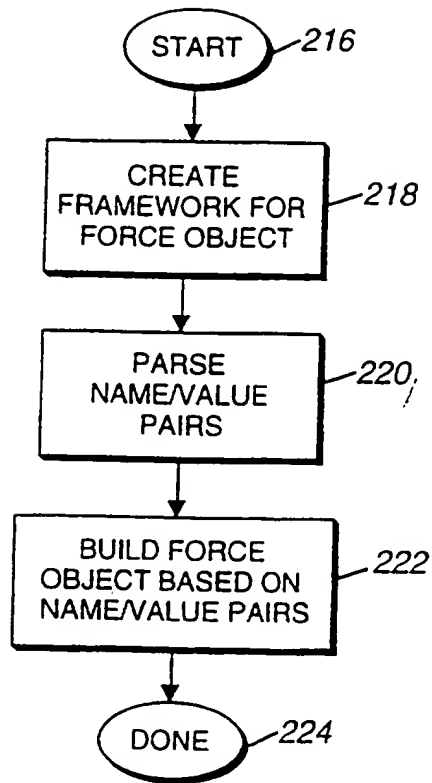


Figure 76

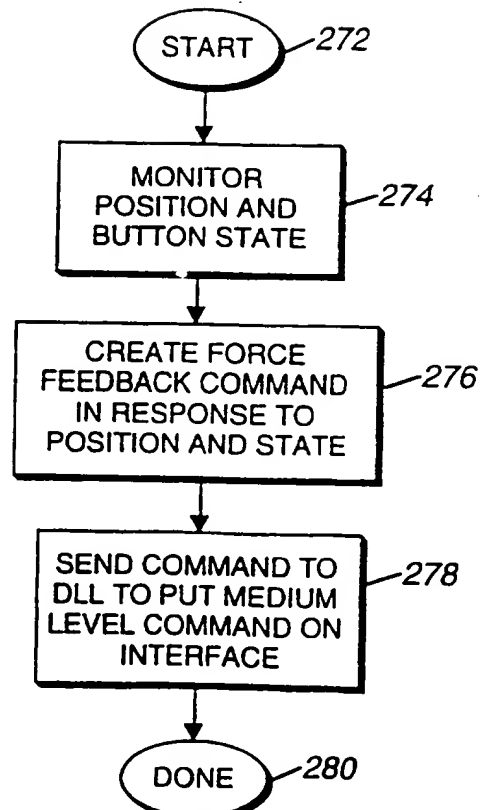
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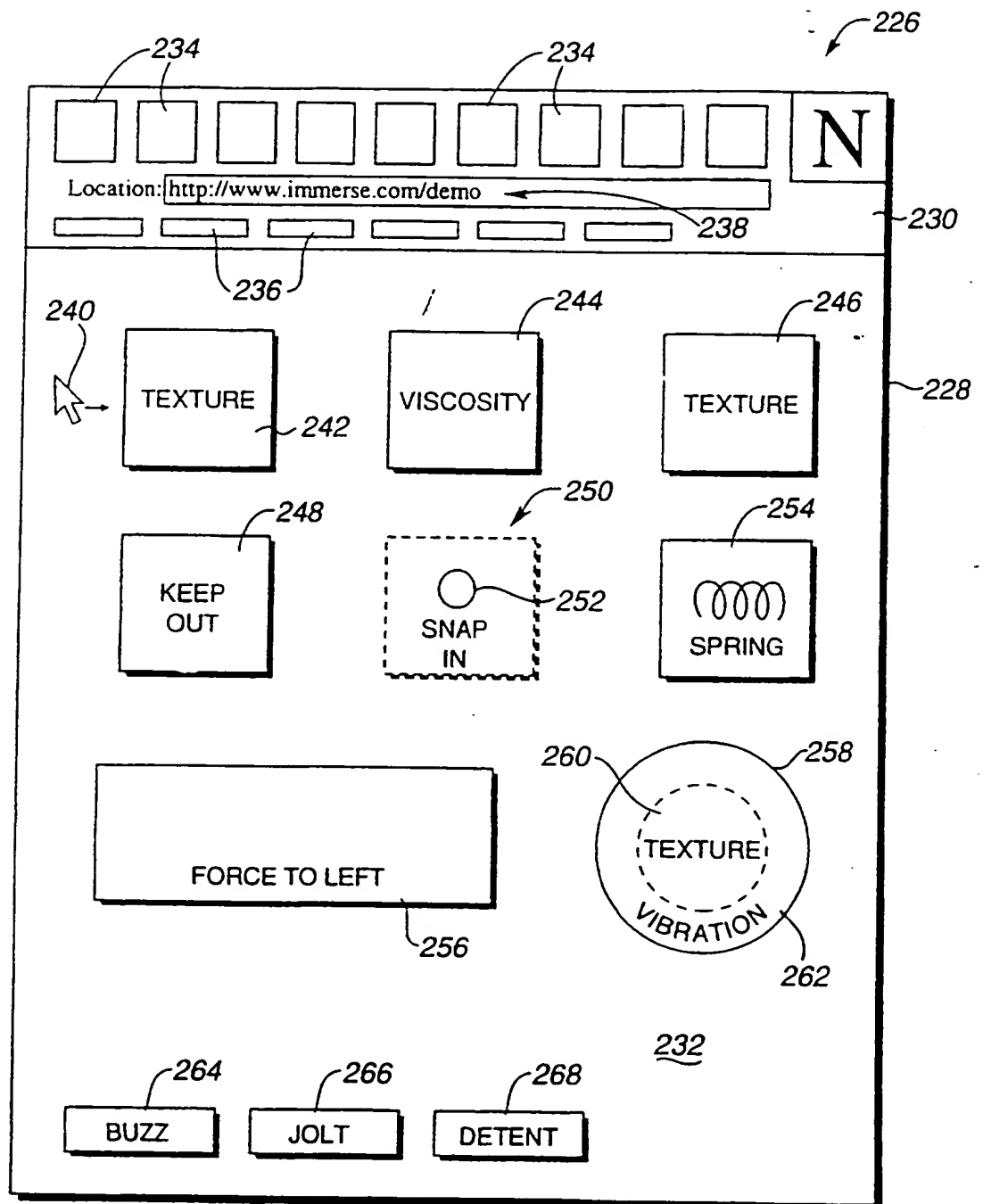
210

*Figure 9*

270

*Figure 10*

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*Figure 9a*



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/12848

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G06F 3/00, 15/16, 17/30

US CL : 395/200.8, 200.33, 200.47, 200.54

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/200.8, 200.33, 200.47, 200.54

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
APS, DIALOG

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,186,629 A (ROHEN) 16 February 1993, cols 2-3	1-49
A	US 5,184,319 A (KRAMER) 02 February 1993, columns 2-6	1-49
Y	US 5,436,638 A (BOLAS et al.) 25 July 1995, columns 5-7	1-49
Y	US 5,459,382 A (JACOBUS et al.) 17 October 1995, columns 2-3	1-49
Y	US 5,386,507 A (TEIG et al.) 31 January 1995, col. 26 line 35 et seq.	1-49

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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*O* document referring to an oral disclosure, use, exhibition or other means	
*P* document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

30 SEPTEMBER 1997

Date of mailing of the international search report

01 DEC 1997

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